An Airborne Cloud-droplet Sampler

著者	Ohtake Takeshi
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An Airborne Cloud-droplet Sampler

By TAKESHI OHTAKE

Geophysical Institute, Tohoku University Sendai, Japan*

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Abstract

An improved cloud-droplet sampler based on SQUIRES and GILLESPIE's idea has been presented for the investigation of the size distribution of cloud droplets in the atmosphere. It is characterized by the following:

(1) The force of the spring is invariable, and its motion is steady.

(2) Sampling of cloud droplets is possible, regardless of the concentrations of droplets.

(3) When projecting out of the cylinder, the rod does not bend, so constant exposure time is secured.

(4) Spare rods are easy to be obtained because of their easy production.

(5) The plane surface of the rod presents clear images under the microscope.

(6) The coated surface of the rod is free from rubbing against the wall of the cylinder, because of the hexagonal structure of the rod.

(7) The sampler is much smaller in size and simpler in mechanism than SQUIRES and GILLESPIE's

I Introduction

Many types of cloud-droplet samplers for use on aircraft have been developed (1, 2, 3,). However, in use they seem to have many shortcomings such as uncertainty of collection efficiency for cloud droplets, lack of uniformity of exposure time in high speed air current, inconvenient operation, etc.

In investigating the size distribution of cloud drops the author used a device developed by SQUIRES and GILLESPIE (3) for a few years, and gained a better understanding of its strong and weak points. The sampler contains glass-rod collectors 3 mm in diameter and 25 cm long and coated with magnesium oxide. The collector is exposed momentarily in clouds. One of the strong points of this device is that exposure time varies from place to place along the rod, so we can freely choose exposure time according to the droplet population of a cloud. Another advantageous point is that its simple-shaped glass rod makes LANGMUIR and BLODGETT's collection efficiency applicable (4). However, when used in high-speed air flow, glass rods are apt to be broken or to be bent. As a result some glass-rod collectors do not return to their original places, and make their exposure time irregular.

To eliminate such disadvantage, the author has recently improved on SQUIRES and GILLESPIE's device.

2 Description of the new device

In use, the instrument in stricked out of the cabin room of the airplane through the copilot's window. A brazen hexagonal rod plated with chromium which is 25.4 cm

* Present adress: Geophysical Institute, University of Alaska, College, Alaska

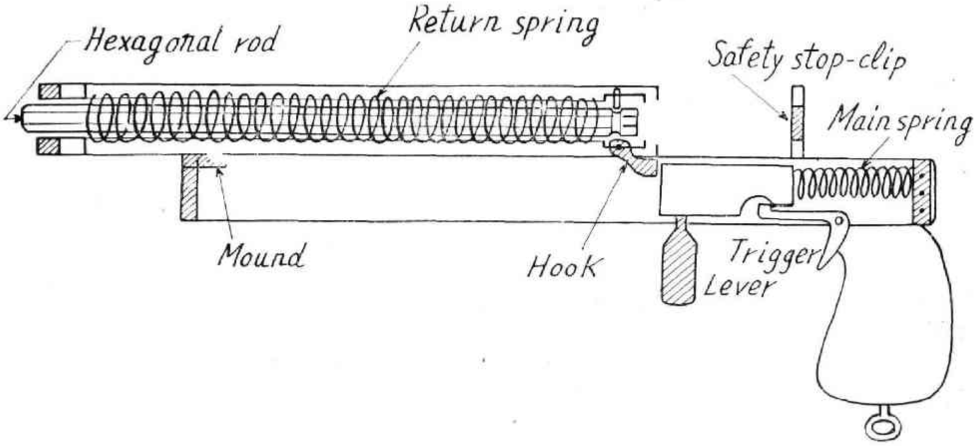

Fig 1. Structure of airborne cloud-droplet sampler.

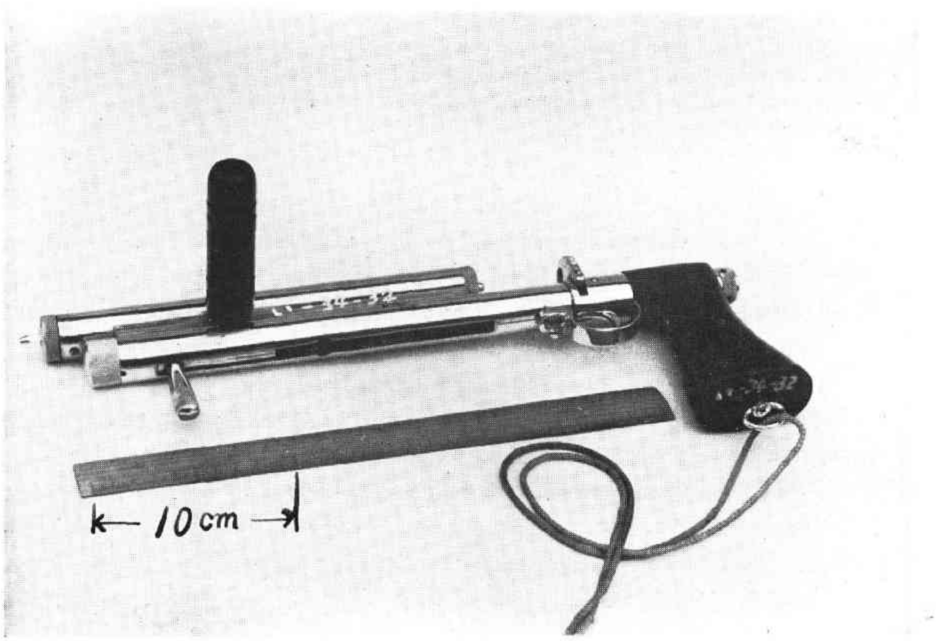

Fig. 2. External appearance of sampler.

long and 8 mm in diameter was used. The structure of this device is shown briefly in Figs. 1 and 2. First, the safety stop-clip is released and a rod is loaded. Then the pulling of the lever compresses the mainspring, thereby storing a strong stretch-out force in the rod. As the trigger is pulled in clouds, the airstream containing cloud droplets comes from the bottom of the page, the hexagonal rod coated with magnesium oxide is pushed out and the return spring is compressed simultaneously. Together with the rod, the hook goes up to the mound ahead, where it is disconnected. Then the rod returns into the cylinder by release of the return spring. The rod makes a trip of 15.6 cm both ways in about a tenth of a second.

In spite of uncertainty of collection efficiency for cloud drops, a hexagonal rod is used for the following reasons:

(1) A hexagonal rod moves back and forth with its sides not touching the wall of the cylinder, so the side coated with magnesium oxide is not damaged at all.

(2) One of the surfaces of the rod is directed perpendicularly to the wind direction so as to obtain clearer images of droplets on this surface. Figs. 3 and 4 are shown the photographs of traces of droplets received by the cylindrical rods and the hexagonal rods respectively. It will be seen that clear traces are obtained over all the surfaces in the case of the hexagonal rods, while they are obtained over relatively small areas around a stagnation line in the case of the cylindrical rod.

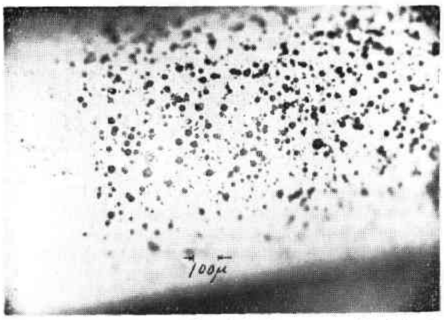

Fig. 3. Photograph of holes on cylindrical rod.

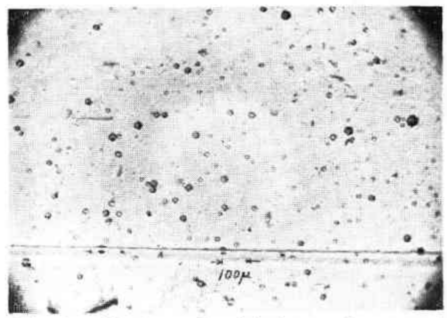

Fig. 4. Photograph of holes on hexagonal rod.

(3) A bar of brass to be cut into nuts is used for making hexagonal rods, so it is easy to procure spare rods, and a lathe is all we need in producing rods.

In conducting microscopic inspection of holes on a coated surface, the light source of reflection is used instead of transmittance.

3 Exposure time

Since the rod projects and then comes back again into the cylinder, the exposure time of a given point varies with the distance from the head of the rod. High speed motion pictures were taken of motions of rods (Pathé Webo M 16 mm camera, 80 frames/sec, with small exposure angle of shutter). Several trials of each rod showed the same results though the phases of images differed from each other. Fig. 5 shows the relation between the distance from the head of the rod to that of the cylinder and the lapse of time since the rod started to project out of the cylinder. So the exposure time at a given point from the head is illustrated by the interval of the two lines, AO and AB. Thus, we obtained Fig. 6.

4 Collection effciency

LANGMUIR and BLODGETT (4) have calculated the collection efficiency E for various geometrical forms such as a sphere, cylinder, and ribbon, as a function of drop radius. Their calculation had widely been used, does not cover the case of the hexagonal prism. The efficiency for the hexagonal prism must be between that for cylinder 8 mm in

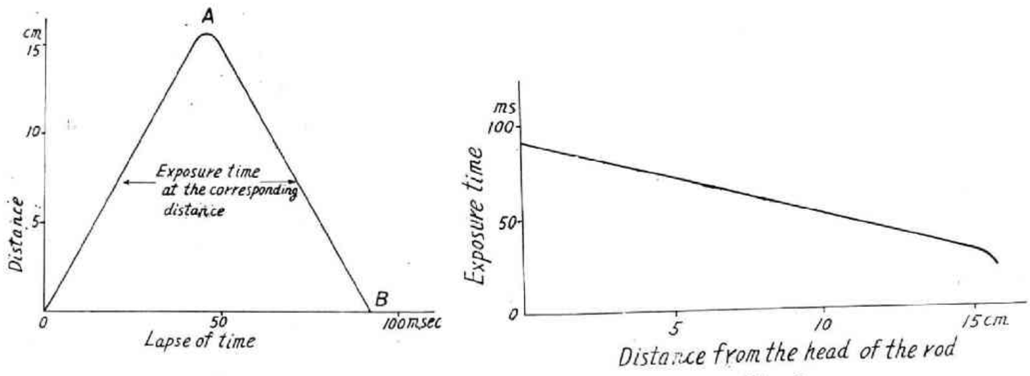

Fig. 5. Fig. 6.

Fig. 5. Relation between the distance from the head of the rod to that of the cylinder and the lapse of time since the rod started to project out of the cylinder.

Fig. 6. Exposure time of points on the rod as a function of distance from the head of the rod.

diameter and that for ribbon 8 mm in width.

Their figures at 50 m/sec and 100 m/sec of relative speeds U, 850 mb and 8°C, are shown in Figs. 7 and 8 respectively. In these figures, we see that more than 90 per cent of cloud droplets larger than 15μ or 21μ in diameter are captured in both cases of cylinder and ribbons. Collection efficiency for the hexagonal rod 8 mm in diameter is similar to that for cylinder 8 mm in diameter in shape rather than for ribbon 8 mm in width, so we have used the dotted curves shown in Figs. 7 and 8 as collection efficiency for the hexagonal 8 mm rod.

5 Relationship between the sizes of the holes on the coated surface of the rod and of the original droplets

MARUYAMA and HAMA (5) investigated the relation between the size of holes on

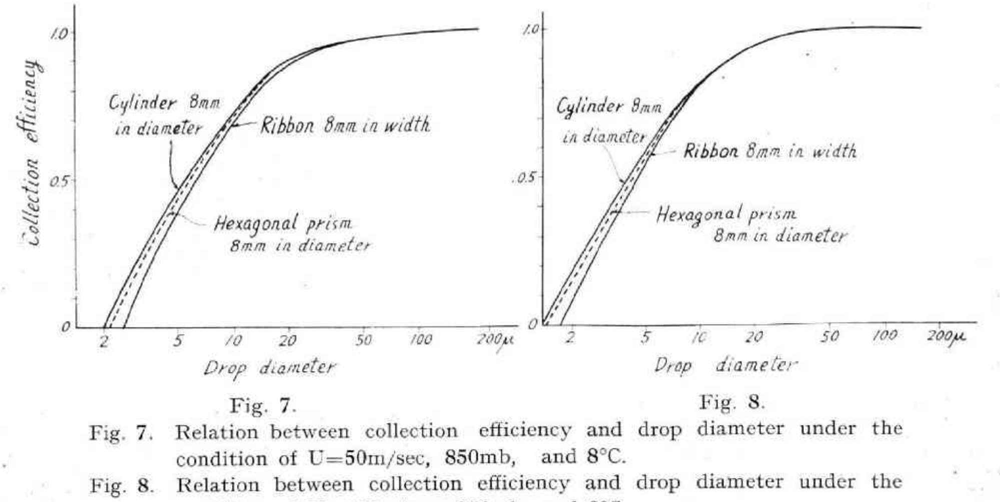

Fig. 7. Fig. 8.

Fig. 7. Relation between collection efficiency and drop diameter under the condition of U=50m/sec, 850mb, and 8°C.

Fig. 8. Relation between collection efficiency and drop diameter under the condition of U=100m/sec, 850mb, and 8°C.

the glass slide coated with magnesium oxide and the diameters of the droplets in clam clouds. Regarding freely falling droplets, they suggested that the ratio of the true drop size to the size of holes on the magnesium-oxide layer was 0.788. In the case of an impact speed, MAY (6) carried out similar experiments for a drop-size range of 20 to 100μ, and found that the ratio of the true drop size to the impression size is constant at 0.86 for droplets larger than 20μ of any liquid. MARUYAMA and HAMA's result and MAY's does not accord with each other. MARUYAMA and HAMA's result is in agreement with the expected value of the ratio, if the fallen drop be assumed to take a semi-spherical shape. It may, then, be considered that MAY's result is too great. In this study, therefore, the ratio of the true drop size to the impression size for high speed droplets was re-examined.

Comparisons of the natural cloud drop-size distributions and the inpression-szie distributions were carried out at a place near the summit of Mt. Zao, when the summit was in the clouds. Size distributions of natural cloud drops were obtained by the so-called freely-falling method at the time when there was no wind at the summit. A constant factor of MARUYAMA-HAMA's 0.788 was used in this measurement. At the same time an electric fan was used to supply the rod with cloud droplets moving at the speed of 50 m/sec. From the impression-szie distributions on rod surfaces, the fractional concentration of drops was calculated in due consideration of exposure time and collection efficiency for each size of drops as described in the former section. Some difference of collection efficiency between true size and impression size of droplets was ignored, because such difference may not be so influencial except in case of droplets of very small size. The original size distributions inferred by the above mentioned two methods were shown in Fig. 9. It will be seen in the figure that the size distribution obtained from the high speed impact method gets more and more deviated from that by the falling method as the drops become larger in size. In this investigation the size distribution inferred from the falling method was assumed to be correct, and the ratio of the true size (of this sense) and the impression size by the high speed imapact method was obtained from Fig. 9 for each accumulated number of drops (ordinate of the figure).

Regarding very large drops such as above 30μ, the ratio could not be determined because such drops were quite few in the clouds. For droplets of less than about 10μ the determination of the ratio, again, became difficult because of too many numbers of such drops. The ratio obtained from the two curves is shown in Fig. 10 together with MAY's and MARUYAMA and HAMA's data for their comparison. For example, the impression size of 50μ in diameter corresponds to the true size of 29μ and the im pression size of 30μ corresponds to the true size of 17.5μ.

Concerning the drops larger than 50μ in diameter and the speed higher than 50 m/sec, their ratios have not yet been worked out. However, according to MAY, there is no change in the ratio for larger drops and higher speed, so that the curve may be extraporated to larger sizes and higher speeds. The ratios for impression sizes less than 17μ are larger than those of MARUYAMA-HAMA's which were determined in the

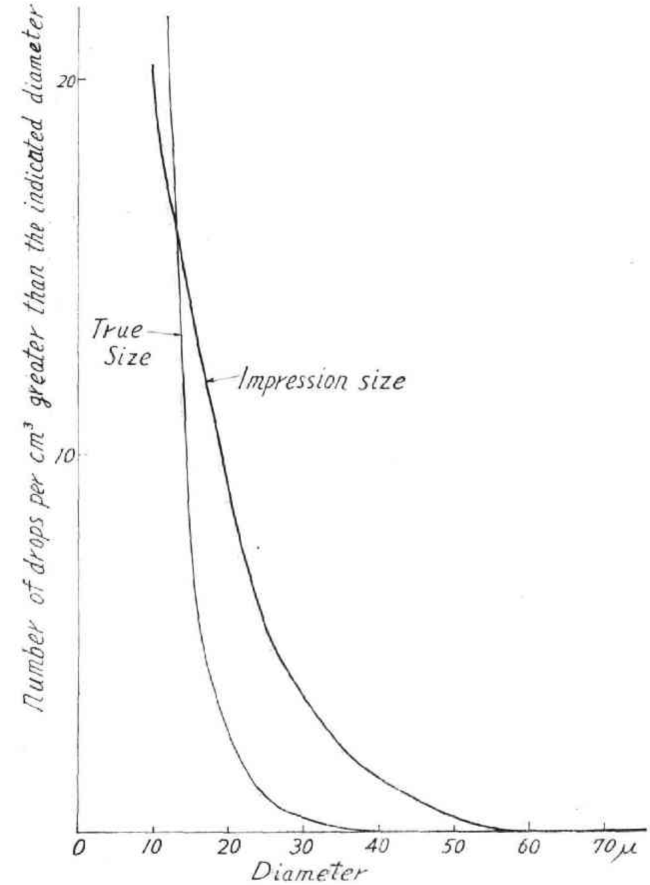

Fig. 9. True size and impression size distribution of natural fogs.

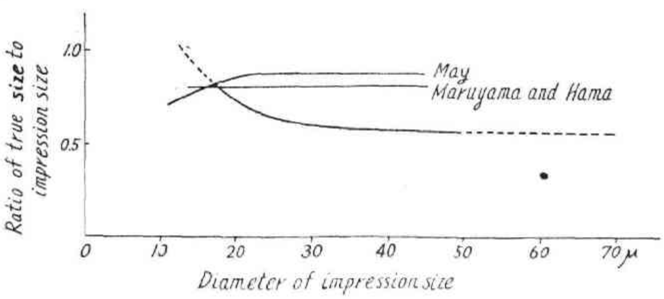

Fig. 10. Factors in deriving true size from impression size of drops.

still air. This seems to be unreasonable. In this connection it is noted that STOKES's fall speed was assumed in the present falling method. However, the experiment was carried out in the atmosphere, so that it was plausible that some error of estimation was involved in the "true" size shown in Fig. 9 for diameters less than 10μ. Taking this into account it is conjectured that the ratio approaches to MARUYAMA-HAMA's value for droplets smaller than 17μ.

Acknowledgement

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